NITROGEN, PHOSPHORIC ACID AND POTASH STARVATION AT DIFFERENT STAGES OF THE GROWTH OF FRAGARIA

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WITH WATER COLOUR DRAWINGS
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Nitrogen, Phosphoric Acid and Potash Starvation at Different Stages of the Growth of Fragaria

By Malcolm B. Davis and H. Hill

The question of the time of application of nitrogenous fertilizers to crop plants has attracted much attention in recent years. The findings to date would appear to indicate that the season of application is a highly important factor where there is a deficiency in any particular plant food or foods. Likewise there has been evidence, suggestive at least, that the effect of a spring application of nitrogen, for instance, was largely dependent upon the growth conditions of the plant in the previous fall. While the majority of cases show, with reference to the strawberry, that fall applications of nitrogen produce rather marked beneficial results, instances are not wanting to indicate that late applications may result in reduced yields. Gardner (1) presents a discussion of the results of seasonal applications of fertilizers and gives a fairly extensive bibliography on the subject. As a result of his own work he concluded that maximum production of flower clusters and number of berries was associated with summer and fall treatments that led to the greatest accumulation of carbohydrates at the time of fruit bud differentiation.

With reference to spring applications, Gardner found that in poor sand spring applications resulted in an actual increase of flower clusters whereas in good soil there was an equally marked decrease in the number of flower clusters produced. He further concluded that, under normal soil conditions, the nutritive condition of the plant itself in spring profoundly influenced the size and set of the fruit, but had little or no effect upon numbers. In the 1925 Report of the Dominion Horticulturist (2) the results of Gardner were somewhat corroborated, it being shown that, even on a fairly rich soil, applications of nitrate of soda made the year previous to fruiting resulted in increased production, with September 15 proving the most desirable date. In the 1924 report of the same division (3) spring applications of nitrate, when made as early as May 3; were shown to have failed to reduce the number of blossoms produced. In 1926 (4) this Division reported on work with a plantation fruiting for the second time and the optimum period for nitrate application appeared to be somewhat earlier in the case of the second year than for a one-year plantation, while spring applications seemed of doubtful value on such a plantation.

Loree (5) obtained his best results from plants receiving their fertilizer both in the spring and summer of the first year, but where it was applied during only one of these seasons the summer application gave better results than the spring.

Hooper (6), working with apples, concluded as follows: " Various physiological processes are affected more or less independently and there are indications that the season when the applications are made is an important factor in determining how these processes are affected."

In the experiments about to be described plant analyses are not available. Only the response of the plant both qualitatively and quantitatively are presented. These results are but the preliminary to a wider investigation along the same lines, which includes a greater range of starvation periods.

PROCEDURE

Plants were secured during the spring of 1926 by taking runners in the field, before they had become attached by roots to the soil, and rooting them in

sandstone in five-inch pots. (For analysis of sand see Davis (7).) By this method the greatest possible uniformity was secured without taking into consideration the inherent potentialities of runners from different parent plants. Food accumulation was limited to that received from the parent plant and the physiological relationship of runner to parent plant was severed as quickly as the runners became rooted. The plants were divided into three groups of nine series each, with each series containing twenty plants.

Owing to our inability to secure sufficient runners rooted at the same approximate time we were obliged to omit certain starvation series covering additional periods in the life of the plant from rooting to fruiting. Further work has been undertaken covering these periods, which we hope to be able to report on in the near future.

Group I constituted a nitrogen starvation group, II a phosphorus starvation group and III a potash starvation group. The nine series of each group were comparable as to the time and period of starvation for the element concerned so it will only be necessary to relate the series for any one group, say, the nitrogen group:—

Series I: Nitrogen lacking throughout, all other elements supplied normally.

Series II: Nitrogen not supplied until May 2 of the fruiting year.

Series III: Nitrogen not supplied until June 6 of the fruiting year.

Series IV: Nitrogen not supplied until June 20 of the fruiting year.

Series V: Nitrogen supplied in deficient quantities throughout.

Series VI: Nitrogen supplied in deficient quantities until June 6 of the fruiting year.

Series VII: Nitrogen supplied in deficient quantities until May 2 of the fruiting year.

Series VIII: Nitrogen supplied in deficient quantities until June 20 of the fruiting year.

Series IX: Nitrogen supplied in excess throughout the expirement.

The phosphorus and potash groups were divided the same as above and the numbers of the series will correspond to these treatments. In addition a series receiving a full nutrient solution was carried.

DESCRIPTION OF FORMULÆ

Applications were made to all series at the rate of 200 cc. of solution per pot per week. The following formula was employed as a full nutrient solution:—

$MgSO_4 7H_2O$	0·576 g.	in 4,000 cc. of water
KH_2PO_4	0·460 "	
KCl	0·128 "	
$Ca(OH)_2$	0·725 "	
NH_4NO_3	2·76 "	

Series and applications requiring no nitrogen received the above formula minus the ammonium nitrate. Series and applications requiring deficient nitrogen received but 0·691 grams of ammonium nitrate in 4,000 cc. of water, the remainder of the formula being similar to the above. Series requiring excess nitrogen received 5·528 grams of ammonium nitrate in 4,000 cc. of water, the remainder of the formula being similar to the above. Where the withdrawal of a starvation factor also influenced the supply of some other element the latter was replaced in the form of another compound at the same rate as was present in the original formula.

FORMULA LACKING PHOSPHORUS

$MgSO_4\,7H_2O$	0·576 g.	in 4,000 cc. of water
$Ca(OH)_2$	0·725 "	
NH_4NO_3	2·76 "	
KCl	0·259 "	

The removal of the phosphorus from the nutrient solution also removed the potassium contained in the compound KH^2PO^4. This was supplied by increasing the amount of KCl so as to provide the requisite amount of potassium.

FORMULA—DEFICIENT PHOSPHORUS

$MgSO_4\,7H_2O$	0·576 g.	in 4,000 cc. of water
$Ca\ (OH)_2$	0·725 "	
NH_4NO_3	2·76 "	
KCl	0·189 "	
KH_2PO_4	0·115 "	

FORMULA—EXCESS PHOSPHORUS AND EXCESS POTASSIUM

$MgSO_4\,7H_2O$	0·576 g.	in 4,000 cc. of water
KH_2PO_4	0·920 "	
KCl	0·128 "	
NH_4NO_3	2·76 "	
$Ca(OH)_2$	0·725 "	

Note that, owing to an error in calculation, the above formula contains both excess phosphorus and excess potash.

FORMULA LACKING POTASH

$MgSO_4\,7H_2O$	0·576 g.	in 4,000 cc. of water
$Ca(OH)_2$	0·476 "	
NH_4NO_3	2·76 "	
$Ca(H_2PO_4)_2$	0·460 "	
NaCl	0·128 "	

The amount of phosphorus as contained in the normal full solution was here supplied in the form of ca'cium phosphate. In order to maintain a normal supply of calcium it was necessary to reduce the calcium hydrate supplied. Chlorine was supplied as NaCl.

FORMULA—DEFICIENT POTASH

$MgSO_4\,7H_2O$	0·576 g.	in 4,000 cc. of water
$Ca(OH)_2$	0·476 "	
NH_4NO_3	2·76 "	
$Ca(H_2PO_4)_2$	0·460 "	
KCl	0·058 "	

FORMULA—EXCESS POTASH:

$MgSO_4\,7H_2O$	0·576 g.	in 4,000 cc. of water
$Ca(OH)_2$	0·476 "	
NH_4NO_3	2·762 "	
$Ca(H_2PO_4)_2$	0·460 "	
KCl	0·400 "	

QUALITATIVE DATA

The series described above, in addition to supplying an opportunity for the study of the seasonal effect of the three elements under consideration, also provided material for obtaining information on the appearance of the plant when suffering from a marked deficiency of nitrogen, phosphorus and potash.

Wallace (8), in his deficiency studies, refers to the appearance of strawberry plants when suffering from the above deficiencies. Our notes practically corroborate the observations of Wallace and undoubtedly, where slight differences, exist, these will be found to be due to different methods of expression.

The nitrogen deficient and nitrogen lacking series began to exhibit evidences of the lack of this element by early fall in their smaller size and paler leaves. By fruiting time in spring all the foliage on the totally lacking nitrogen series was yellow and dwarf, many of the original leaves having died down and the newer ones being much smaller. Red tints developed before the fruit was harvested. (See Fig. I).

In the potash series those lacking this element exhibited foliage of a good dark green colour until well into the fruiting season, but the plants were not as large nor as vigorous as the full nutrient solution plants. The foliage gradually became dull, losing its lustre and by the end of the fruiting season the leaves began to curl considerably and exhibited a bronzing with considerable purple on the under side of the leaf. (See Fig. 2.) This purple colour, by late summer of the first fruiting season, had spread to the upper surface and occupied the entire margin of most leaves, with the centre only showing green. The series only deficient for potash exhibited this also, but to a less extent.

The phosphorus lacking series exhibited foliage of a dark, dull green colour, of small size with short petioles. By the end of the fruiting season they developed the bronzing similar to the potash series, but accompanied by a reddish-brown tint instead of the distinct purple. This spread over the entire leaf except a small portion of the centre. The veins stood out rather noticeably and the leaf tissue seemed lifeless, thin and paper-like. (See Fig. 3.) In the excess series those receiving excess nitrogen exhibited a darker green than any, otherwise they appeared quite normal. The excess phosphorus series showed foliage of a vigorous nature, but a little lighter in colour than the normal, curling after the fruiting season, with red tints. Excess potash showed in lack of vigour, small leaves, with considerable reddish tint on the margins. It would be interesting to determine if this reddish colour in the case of the excess phosphorus and potash series was not due to a comparative lack of nitrogen, or, in other words, to the width of the nitrogen, phosphorus and nitrogen, potash ratios.

QUANTITATIVE DATA

As a measure of response to the treatment given, the number of blossoms produced by each plant was counted and, later, the number of fruits produced, the per cent of set being then calculated. The probable error was determined for each series by the formulæ:

$$D = \sqrt{\frac{\Sigma F (V^2) - M^2}{N}}$$

$$eM = \frac{\pm \cdot 6745 D}{\sqrt{N}}$$

Where Σ = summation, F = frequencies, V = variables, N = the number, M = mean, D = standard deviation and eM = error of mean.

Fig. 1—Foliage tints developed by nitrogen lacking series.

Fig. 2—Foliage tints developed by potash lacking series.

FIG. 3—Foliage tints developed by phosphorus lacking series.

Tables 1, 2 and 3 give the results for the nitrogen, phosphorus and potash groups respectively.

TABLE 1.—Blossom Count and Set from the Nitrogen Group

Series	Treatment	Bloom	Per cent set
N-1	Nitrogen lacking throughout	16·33 ± 1·06	64·66
N-2	" " until May 2/27	21·33 ± 1·65	53·28
N-3	" " until June 6/27	16·50 ± 1·08	68·63
N-4	" " until June 20/27	15·50 ± 1·13	57·42
N-5	" deficient throughout	16·94 ± 1·73	59·94
N-6	" " until June 6/27	20·63 ± 4·96	64·79
N-7	" " " May 2/27	21·76 ± 1·05	62·96
N-8	" " " June 20/27	18·63 ± 1·59	56·17
N-9	" supplied in excess throughout	16·67 ± 1·32	68·22

Table 2.—Blossom Count and Set from Phosphorus Group

Series	Treatment	Bloom	Per cent set
P-1	Phosphorus lacking throughout	14·12 ± 1·03	36·14
P-2	" " until May 2/27	18·25 ± 1·24	76·90
P-3	" " " June 6/27	17·22 ± 0·79	64·44
P-4	" " " June 20/27	14·24 ± 1·04	54·40
P-5	" deficient throughout	14·88 ± 1·09	66·67
P-6	" " until June 6/27	17·29 ± 1·00	76·71
P-7	" " " May 2/27	19·89 ± 1·07	67·58
P-8	" " " June 20/27	17·06 ± 0·89	53·25
P-9	" supplied in excess throughout	16·56 ± 1·16	73·77

Table 3.—Blossom Count and Set from Potash Group

Series	Treatment	Bloom	Per cent set
K-1	Potash lacking throughout	14·67 ± 1·36	59·35
K-2	" " until May 2/27	16·82 ± 1·40	67·00
K-3	" " " June 6/27	16·59 ± 1·27	56·64
K-4	" " " June 20/27	16·25 ± 1·00	59·76
K-5	" deficient throughout	18·00 ± 1·17	50·32
K-6	" " until June 6/27	17·22 ± 1·22	62·00
K-7	" " " May 2/27	14·75 ± 1·41	73·98
K-8	" " " June 20/27	16·89 ± 1·17	60·83
K-9	" supplied in excess throughout	17·00 ± 1·38	58·99
Full nutri	ent solution throughout	21·30 ± 1·20	70·36

An examination of the results reveals (1) that where either nitrogen, phosphorus or potash was lacking throughout the experiment the yield was significantly lower than that of the full nutrient series, (2) that the lack of phosphorus apparently has more effect on set than either lack of nitrogen or potash, (3) that the correction of the nitrogen deficiency, not later than May 2 in this instance, brought the plants back to normal production, (4) that while the correction of the phosphorus and potash starvation by May 2 and June 6 resulted in an increase over the complete lack of these elements, it did not entirely correct the decrement below the maximum, (5) that in the case of the potash group there is some doubt as to whether the spring correction of the potash deficiency actually increased the yield or not, and (6) that excess of nitrogen, phosphorous or potash resulted in decreased yields of about equal magnitude.

SUMMARY

(1) Series of strawberry plants were grown in pure sand and starved for different periods for nitrogen, phosphorus and potash.

(2) Information of symptomatic value in diagnosis of malnutrition was obtained.

(3) Phosphorus seemed to be fully as important, if not more so, than nitrogen in influencing set.

(4) Where plants have been starved during the fruit bud formation period, for either element, very early spring correction of the starvation results in increased flower production.

(5) Whether this increased flower production is due to the formation of new buds or the development of buds formed in the fall, which would not otherwise develop, is not known.

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